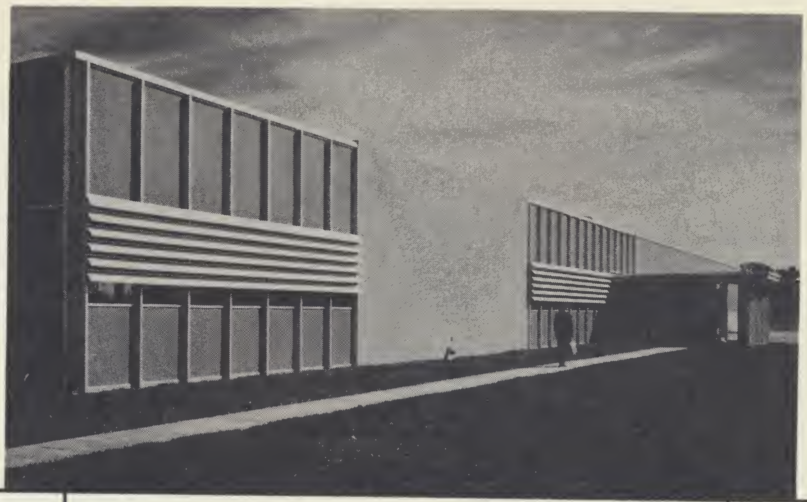
DSD

spotlight on memories



Bryant Computer Products' headquarters (shown above) are located at Ex-Cell-O Corporation's forty-acre Technical Center in Walled Lake, Michigan—a Detroit suburb. The division's sales and administrative staffs operate out of this facility, and all disc file and electronic systems engineering, assembly and final testing are done here.

Manufacture, assembly, and final test of Bryant magnetic drum storage units takes place in Springfield, Vermont, former location of all Bryant operations. It was here that Bryant Chucking Grinder Company entered the magnetic drum field in the early 1950s. For more than 50 years, Bryant Chucking Grinder had produced precision rotating spindles and integral electric motors for its line of internal grinding machines. The diversification into magnetic storage drums was a natural extension of the firm's metalworking background.

Bryant Chucking Grinder was acquired by Ex-Cell-O Corporation of Detroit in 1958. Later, Bryant Computer Products was given full divisional status with Ex-Cell-O and part of the operation was moved to Walled Lake.

EXPORT SALES

SPRINGFIELD (VT.) OFFICE
J. Alan Spahr, European Reg. Sales Mgr.
P.O. Box 620
Phone: 802 Turner 5-2141
TWX: 710-227-1700

CANADA

OTTAWA, CANADA
Communication Systems, Inc.
E. Benerkritis
P.O. Box 973
Phone: 613-235-8700

JAPAN AND WESTERN EUROPE

(except West Germany, France and Belgium)

LOS ANGELES 4, CALIFORNIA
Munzig International, Inc.
Art Munzig, Jr.
212 South Western Avenue
Phone: 213 DUnkirk 2-1276
TWX: 213-380-8885

ZURICH 8, SWITZERLAND
Munzig International, Inc.
George A. Tingley
Muhlebachstrasse 9
Phone: 051 47 99 66 Telex: 53-873
Cable: Munzigint Zurich

JAPAN

TOKYO, JAPAN
Munzig International Japan, Inc.
Thomas Palmer
No. 19, 2-Chome, Omotemachi
Akasaka, Minato-ku, Tokyo
Phone: 401-8785 402-4337
Telex: TK-2859
Cable: Munzigint Tokyo

FRANCE, WEST GERMANY AND BELGIUM

NEW YORK 20, NEW YORK
B. Freudenberg, Inc.
Howard May
50 Rockefeller Plaza
New York 20, New York
Phone: 212 PLaza 7-9130

BRYANT COMPUTER PRODUCTS

850 Ladd Road, Walled Lake, Michigan • U.S.A. • TEL. 624-4571, TWX 810-231-7190
A DIVISION OF EX-CELL-O CORPORATION

criteria for selecting random-access mass memories

Frank J. Lohan

Part I of a two-part series on mass memories, this article indicates the characteristics inherent in disk files that must be considered when using these memories in a system.

FOR MANY APPLICATIONS sequential-access, bulk memories such as magnetic tape and punched cards do not provide the necessary accessibility, while random-access, high-speed memories such as cores and delay lines do not provide sufficient mass storage capabilities. However, in random-access mass memories—notably drums and disk files—the salient features of these two extremes are combined to give the user random-access to many short tracks of serially recorded information with storage capacities ranging from 100 million to 1.6 billion bits.

Although at least one large drum system (Univac's 490 Fastrand) has competed successfully with disk files in applications requiring 300 million or more bits of storage, most users today have gone to disk files for storage requirements exceeding 100 million bits.

With the exception of Fastrand which is really a two-drum system, commercially available drums range in capacity up to 35 million bits. These drums can be used in tandem to provide an essentially unlimited storage capacity. However, for large-storage applications requiring more than a few drums, the disk file offers advantages in access time and cost-per-bit stored.

Single-disk memories often have extremely important special-purpose roles to fill, and usually meet stiff competition from good drum memory systems. When rapid access to a comparatively large store of information is critical and where space requirements must be minimized as in military airborne applications, single-disk memories are indispensible.

Multi-disk memories (a file of up to 50 disks mounted in a single memory unit) are unlike single-disk units in that they provide a unique means of obtaining high-

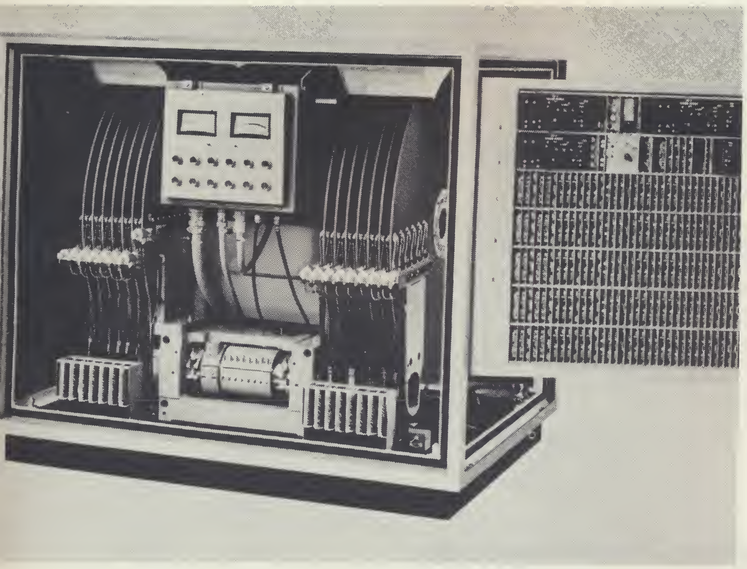


FIG. 1. Disk file stores 845 million bits at 600 bpi (Bryant 4000B).

speed random-access to a large memory store. A typical file is shown in Fig. 1.

Disk File Applications. Locating a desired record at a known location in an information store, reading it into data processing equipment, changing it as required and writing it back into the information store on a random-access basis is becoming more and more essential in most medium and large scale computer systems.

Random-access to a large store of constantly updated information is, of course, mandatory in operational on-line control systems. However, in control systems where the computations and sequencing of programs is generally well-defined and known beforehand, high-speed serial access may be perfectly good. Relatively small amounts of random-access memory may be useful, for example, in systems using unpredictable branching to alarm and emergency programs.

For communications, disk files have served to date for altering information transfer rates. Through utilization of an ultrafast magnetic core memory as a logic programmer and the disk file as a data buffer, communications specialists have been able to combine high-speed data processing with an extremely flexible data store to produce maximum efficiency.

There is now a trend toward using on-line random-access systems with disk files for straight scientific applications, disk files have already entirely replaced magnetic tape.

Disk files are also used with sophisticated inquiry and readout equipment as the main storage or as a buffer memory. In peripheral equipment such as visual computer readouts the disk file makes possible a constant (no flicker) variable size display.

The Disk. Disks used with files range in size from 14 to 48 inches in diameter and are normally less than one-half inch thick. Disk mass is usually kept to a minimum by using a nonmagnetic base material such as aluminum or magnesium, which is comparatively easy to plate spray.

Generally, the recording surface is produced by electrodepositing or spraying a magnetic iron oxide or alloy coating onto the faces of the disk. To obtain the 150 microinch or less head-to-surface separations required for the high-density recording required, disks must have a maximum flatness excursion of 0.0004 inch with a maximum frequency of once per revolution. Also, the disks must be dimensionally stable and have surface finishes of 5 microinches or better.

Surface Anomalies. The recording surfaces of the disks can never be completely free of all data endangering anomalies. In the manufacturing process leading to

FIG. 2. Optical inspection of the disk surface precedes electrical testing in the manufacturing process.

a finished disk (see Fig. 2), there are several major physical reasons for a minor surface defect to occur. Some of the more important of these are pits in the disk surface, agglomerate in the magnetic coating, trapping of volatile materials, bumps or mounds and physical scratching by dust particles.

Anomalies in the magnetic coating could result in the potential loss of data integrity over a small number of successive bits (usually fewer than six) in the vicinity of the anomaly. Anomalies are stable; once in existence, they remain in the same location, retain their characteristics and do not affect other areas of the disk. To assure reliabiliy of disk file operation in the field, these anomalies which can threaten data integrity under either normal or marginal conditions should be detected and catalogued by some type of marginal checking scheme. Marginal anomalies should be as rigorously provided

for in the field systems as more pronounced anomalies.

File Assembly. Disk files are made by fastening disks to a single, precision spindle which is mounted either vertically with an end support or horizontally with a center pedestal support. Because anywhere from one to 50 disks can be mounted, disk files provide an attractive degree of modularity.

Driven by an induction motor either from one of the ends or its center, the spindle must have an indicated total runout at its ends of approximately 0.0002 inch. Depending largely on the number of disks installed on the spindle, disk files range in speed from 450 to 1,800 rpm. Large disks are being assembled in production-built files with total runouts of 0.010 inch or better and with a dynamic balance held to less than 0.000090-inch.

Head Mounting. Various techniques have been worked out to solve head mounting difficulties in a disk file. The simplest but most expensive approach for large-capacity files is to mount one head for each track. This approach eliminates the need for moving the head relative to the disk, thus giving better access time than other methods. However, it would take approximately 38,400 heads—which are precision-built and, therefore, more expensive—to process the information presently handled by 300 heads or less in systems with moving heads.

Another technique is to mount an opposed pair of read/record heads on the ends of a two-pronged positioning arm, with one head serving each side of the disk. By positioning the arms (or a whole group of similarly-constructed, mechanically-coupled arms) in response to select signals, the heads are positioned over individual desired tracks and the information written in or read out. Although this method requires only two heads per disk and is, therefore, economical, the access time suffers considerably.

A third approach is to use more than one head on each side of the disk. In the case of Bryant Series 4000 Disc Files, 12 heads are mounted on a positioning arm, six on each side. Instead of servicing both sides of the same disk, however, this positioner serves facing sides of two adjacent disks. Each head travels over 128 tracks within its particular band. Thus, 300 heads are needed for a 25-disk file.

While not as expensive as the head-per-track method. this technique is more costly than the head-per-side method. However, optimum use is made of each side since the pulse density and speed variations (a function of radius) can be grouped. A single head need not cope with the total variation.

Head Positioning. The head-per-track approach very closely resembles that used on drums. The other approaches, however resemble mechanisms to position the heads very rapidly with extreme accuracy. A positioner is shown in Fig. 3.

Ramac, the first commercially available disk file, vintage 1956, had 50 magnetically coated metal disks rotating in horizontal planes at 1200 rpm. A single access arm moved up or down to select the appropriate disk, then positioned into the appropriate track. An additional access arm was available so one could be reading or writing while the other moved to the next disk.

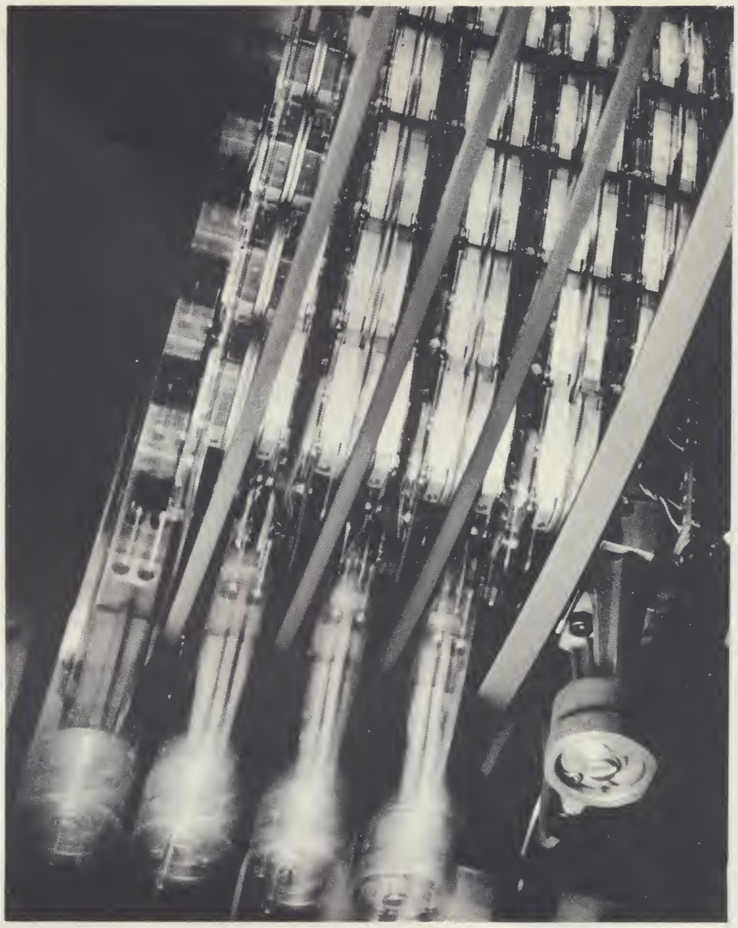


FIG. 3. Open-loop, mechanical-hydraulic head actuator drives all head bars simultaneously to any of 128 positions.

Maximum access time to a bit on a track once the head was positioned on that track was 50 msecs. But because the access arm might have to move past 49 disks before it could move to the selected track on the selected disk, maximum access ran as high as 800 msecs.

Positioners developed since Ramac have been of two basic types; electromechanical and electrohydraulic. Regardless of the mode of operation, these positioners are designed to keep the heads located a relatively large distance from the disks when the file is not operational.

In one arrangement, two electromechanical linear positioners move an arm mounting eight heads (four for each disk face) to any one of 100 positions. The primary positioner shaft is connected to a steel ribbon linked directly to the head array assembly. Movement of the primary positioner results in an identical movement of the head array.

In another arrangement, an electrohydraulic positioner moves an arm mounting 12 heads (six for each

of the file itself, particularly in the area of developing electronic circuits capable of handling sophisticated data format schemes.

A concerted effort by data systems designers is underway to develop techniques which will realize the fullest potential of the device. This task is far from finished and represents the greatest challenge—and the greatest present problem—to the disk file user.

Cost. Despite the relatively high cost of advanced random-access mass memory systems, the need to solve problems either not handled before or which had been done in a clumsy fashion has made the disk file worthwhile. Use of such systems has increased substantially because disk file hardware has become available which provides considerable capacity with acceptable access time at a low cost per bit.

For now, the alternatives to the disk file—thin films, cryogenic devices and the like—appear to be far off in realization.

FRANK J. LOHAN, Disc File Product Manager for Bryant Computer Products, is a 12-year man in digital computer design. He is responsible for all design engineering and production associated with Bryant's Disc File program.

With Bryant since 1957, he previously spent seven years with Remington-Rand Univac in Philadelphia as a development engineer for magnetic peripheral equipment. Mr. Lohan received a BS in electrical engineering from Drexel Institute of Technology, and is a member of the IEEE.

Max. density (bpi)	Max. disk capacity (Mbits)	Max. file capacity (Mbits)	Disk speed (rpm)	Avg. Latency time (msec)	Positioning time min. (msec)	Positioning time avg. (msec)	Positioning time max. (msec)	Transfer rate (Kbps)
500	4.6	27.6	2400	12.5	75	75	75	460
500	20.16	161	1200	25	90	100	150	500
500	27.82	668	1200	25	—	65	—	500/*7*
600	65.72	390	1200	33	—	74	—	640
600	65.72	854	1200	33	—	74	—	640
600	65.72/*9*	1643	1200	33	—	74	—	640/*9*
1000	14.40	57.6	1500	20	20	20	20	100/*8*
400	9.68	155	1200	26	—	174/*6*	—	500
600	14.40	920	1200	26	—	92/*6*	—	697
600	14.40	920	1200	25	—	174/*6*	—	1394
600	14.40	920	1200	25	—	89/*6*	—	697
450	13.9	278	1790	17	50	120	180	540
450	13.9	556	1790	17	50	120	180	540
—	58.3	1166	1790	17	50	120	180	1104
—	58.3	2332	1790	17	50	120	180	1104
1000	2.40	24	1500	22	—	250	400	—
—	3.20	80	1200	25	100	500	800	—
—	3.20	160	1200	25	100	600	800	—
840	51	306	900	33	—	35	70	356/*8*

6. Access time is defined as the total elapsed time including all delay and latency from initiation of seek to the instant the data is available to read or write/check.
7. With two-clock system, works at 375 and 600 Kbps.
8. Characters per second.
9. Bryant's 12-bit parallel operation can achieve 5.4 Mbps transfer rates at 448 Kbps write/head frequency and 285 bpi packing density, with capacities approximately halved per disk and file from the values indicated.

FIRST PRINTING APRIL 15, 1964. PUBLICATION NO. BCAR-101-4-64. LITHO IN U.S.A.

BRYANT COMPUTER PRODUCTS NEWS

850 Ladd Road, Walled Lake, Michigan 48088 • U.S.A.
TELEPHONE: 313-624-4571, TWX. 810-231-7190
A DIVISION OF EX-CELL-O CORPORATION

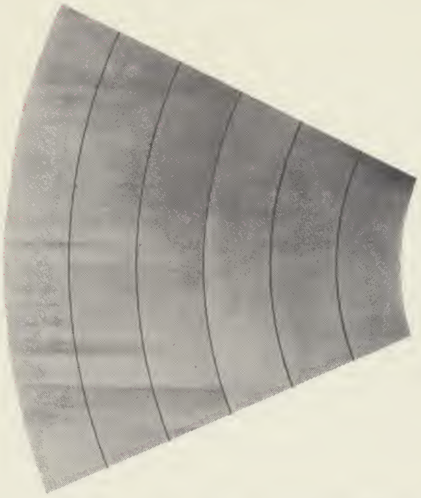


Fig. 1 Pattern was taken from a disc containing data used in actual day-to-day data processing. Zones 1, 2, and 3 were recorded at 224kc; Zones 4, 5, and 6 at 448kc with bit interlacing. Rotational velocity of the disc file was 1200rpm.

A BIT OF INFORMATION

Magnified 1000X, Here's what a Magnetic Bit Looks Like

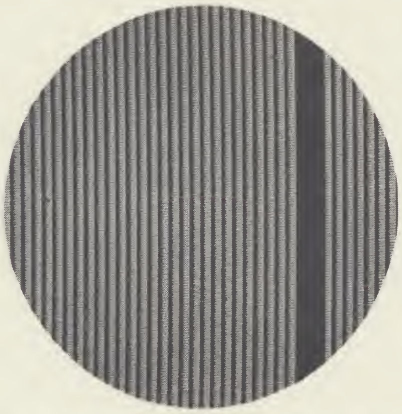


Fig. 2 Magnification of pattern in Fig. 1 shows relationship of data track.

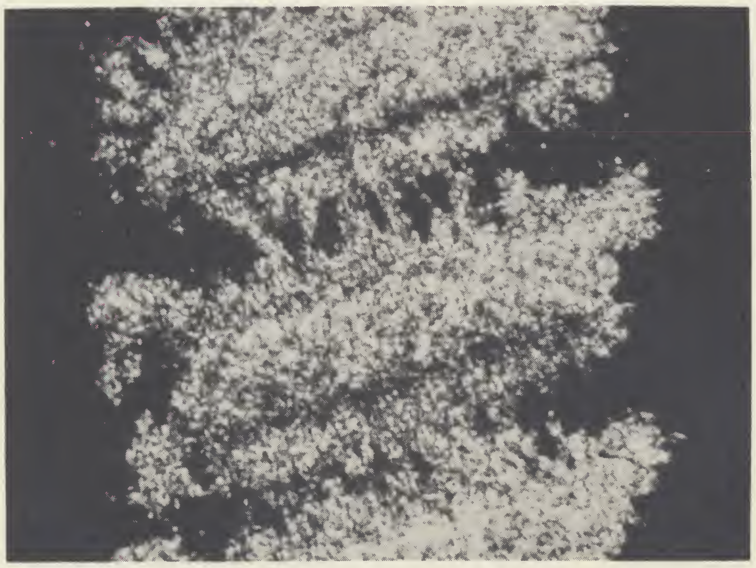


Fig. 3 A bit blown up.

To manufacturers and users of magnetic data storage devices, a bit has real substance — it is defined as a single magnetically polarized spot in a group of spots. In the case of Bryant Computer Products' disc files, these spots are recorded within 768 concentric tracks on each disc face. These tracks are allocated to six recording zones on a 128-track-per-zone basis. Each zone is serviced by a read-write head which is digitally positioned to any one of the 128 tracks.

The bits on the disc surface can be visualized by applying a volatile solution containing micron-sized iron particles which are attracted to the magnetized area. When the base material evaporates, the iron particles adhere to the disc face giving the distribution pattern shown in Fig. 1. By magnifying this pattern 12½ times, the relationship of the tracks can be clearly discerned as shown in Fig. 2. A further magnification of 80 times permits us to see a bit blown up to 1,000 times its original dimensions. (The original dimensions of the bit were 0.0035″ x 0.010″, which was blown up to 3.5″ x 10″, but it was then reduced to 4″ for printing here.

EDITOR: *We thank Bryant Computer Products for this bit of information.*
BRYANT: *It didn't hurt a bit.*

Reprinted from COMPUTER DESIGN, July, 1964 • First Printing - August 21, 1964 • Publication No. BCAR-102-8-64

DATA STORAGE - Basic storage element in Bryant's Series 4000 Disc Files is a disc 39 inches in diameter which is coated on both sides with a proprietary magnetic oxide material. Information is recorded within 768 concentric tracks on each disc face by six magnetic read/write heads. A digital hydraulic positioner moves the heads to any one of the 128 tracks accessed by each head.

One digital positioner is supplied for an entire file; thus, all heads on all disc faces are moved simultaneously. This action permits the use of an extremely efficient drum (or cylinder) operating mode in which each positioning operation accesses 1/128th of the full file capacity. In this mode of operation, the file can be pictured as 128 magnetic drums meaning - for a maximum capacity file - each can store over 12,000,000 bits!

ACCESS TIME - Random access time within each drum or cylinder is extremely fast - averaging 25 milliseconds - because this period includes only disc latency, that is, the delay involved as a memory location rotates around to a position under the magnetic head. Positioning time is added only when switching from one drum to another.

TRANSACTION RATE - Disc file operating speeds are best measured in terms of transactions per unit of time. This rate, of course, varies with the computer used, the type of transaction and the size of the file. Rates of Bryant files in operational use have exceeded 25,000 transactions per hour on a full random access basis. Significantly higher rates have been obtained by minimizing the number of positioning operations and the distances moved. Optimum utilization of the cylinder mode permits rates up to 144,000 transactions per hour.

PRODUCT ASSURANCE - At Bryant, product assurance means assuring that products delivered fully satisfy the purchase specifications with regard to capability, reliability and quality. A complete product assurance organization reporting directly to general management has been established to carry out this function.

Responsibilities of the product assurance organization begin during equipment design when reliability engineering personnel assist in development of hardware specifications and component selection. This early effort is followed by rigid quality control activity which assures that vendors and fabricating departments fully comply with the specifications. A quality control section also enforces adherence to production and assembly procedures, and conducts preliminary and final acceptance tests of the deliverable equipment. Finally, the product assurance organization is responsible for operational failure analysis and the subsequent feedback of their conclusions to design engineering.

This product assurance program is in full effect for the Bryant Series 4000 Disc Files. In addition to the above mentioned functions, the program requires thorough testing of all sub-assemblies prior to installation on a file.

GENERAL SPECIFICATIONS FOR BRYANT SERIES 4000 DISC FILES*

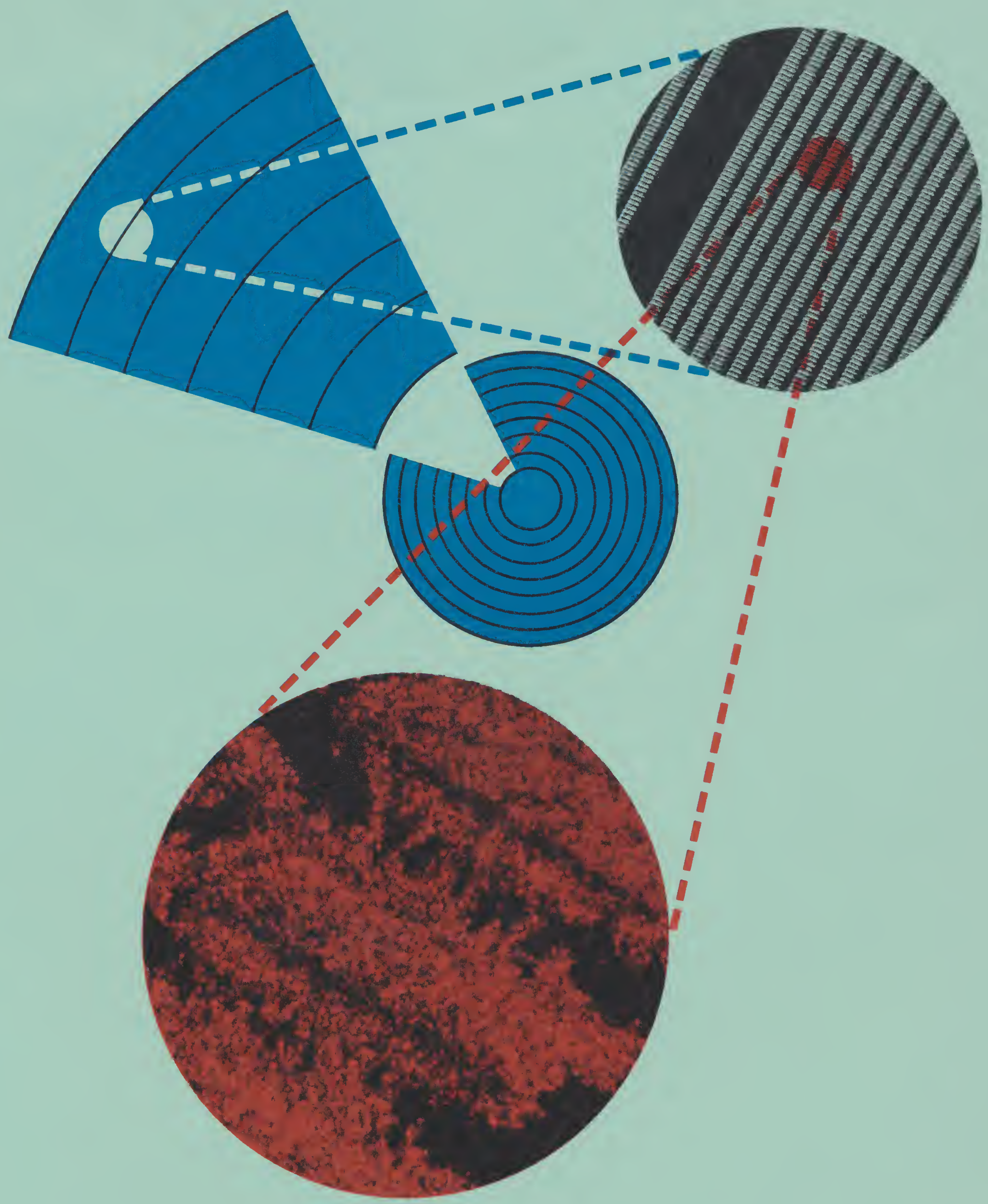
CHARACTERISTIC	SELF-CLOCKING BLOCK-FORMAT RECORDING		SINGLE-BIT ALTERATION RECORDING	
TRACK CAPACITY (Maximum)				
Zone 1	23,580 Bits		11,200 Bits	
Zone 2	31,140 Bits		14,800 Bits	
Zone 3	38,640 Bits		18,354 Bits	
Zone 4	46,200 Bits		22,400 Bits	
Zone 5	53,700 Bits		25,507 Bits	
Zone 6	61,260 Bits		29,098 Bits	
DISC CAPACITY (Maximum)	65×10^6 Bits		31×10^6 Bits	
FILE CAPACITY (Maximum)	1625×10^6 Bits		775×10^6 Bits	
FREQUENCY AT MAXIMUM CAPACITY	900 rpm	1200 rpm	900 rpm	1200 rpm
Zone 1	354 KC	472 KC	168 KC	224 KC
Zone 2	468 KC	623 KC	222 KC	296 KC
Zone 3	579 KC	773 KC	276 KC	367 KC
Zone 4	693 KC	924 KC	336 KC	448 KC
Zone 5	806 KC	1.074 MC	383 KC	510 KC
Zone 6	923 KC	1.230 MC	437 KC	582 KC
RECORDING DENSITY	600 BPI, Maximum		285 BPI, Maximum	
DISC DROPOUTS	Zero		5 Maximum, per Disc	
OPERATING TEMPERATURES	50°F to 90°F		60°F to 80°F	

* All Bryant files use six data heads per disc surface, contain 39-inch diameter discs, have a track density of 64 tracks per inch, and can be purchased with rotational speeds of 900 or 1,200 rpm. There are 768 tracks per disc side. Files with six-zone formaing have 128 tracks per zone. Operating principles of Series 4000 Disc Files are detailed in Bryant publications BCPB-101-9-63; complete technical specifications are contained in Bryant technical specification ES-174.

First Printing — November 11, 1963
Publication No. BCPD-101-11-63

INSTRUMENTS AND CONTROL SYSTEMS

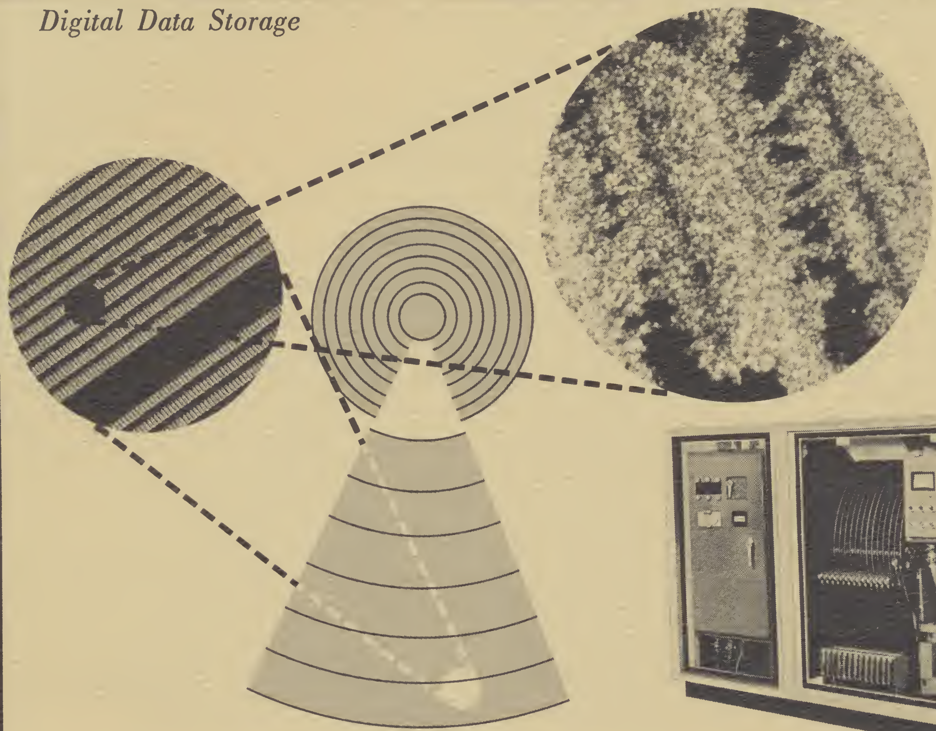
JOURNAL OF THE SCMA • PRECISION MEASUREMENTS ASSOCIATION • STRAIN GAGE READINGS



JULY 1964

in this issue:

A RIMBACH PUBLICATION



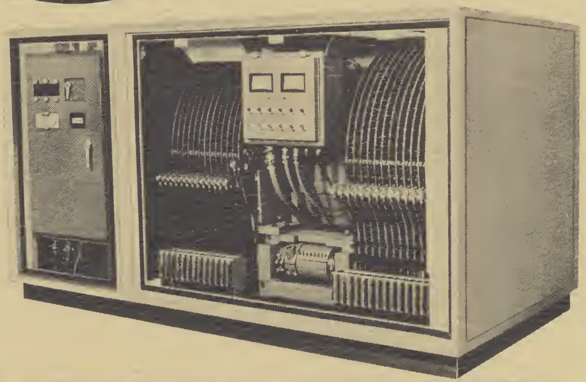


FIG. 1. SERIES 4000 disc file (below). Multiple magnification of a disc surface and tracks reveals several recorded bits (left).

DISC FILE MEMORIES

MARVIN G. SCHAAR
I. DONALD BIONDO
Bryant Computer Products
Division of Ex-Cell-O Corp.

The disc file memory bridges the gap between low-capacity high-speed memory drums and cores, and high-capacity slow-speed magnetic tape memories.

USING a biological analogy, disc files can be thought of as a "genus" of the rotating memory "family" which is part of the magnetic storage "order." Magnetic drums are another "genus" of the same family; tapes, cores and delay lines are examples of other families. Within the disc file "genus" are two distinct "species": the moving-head and fixed-head (or head-per-track) types. The moving-head "species" consists of several "varieties" including mechanical and electrical head-positioning types. The disc files described use mechanical positioning.

Disc files consist of motor-driven, rapidly-rotating circular plates; the disc surfaces are coated with a magnetic material which is capable of permanently storing magnetic signals. Although single-disc memories are being built and often have important special-purpose roles to fulfill, they usually meet stiff competition from good drum memories. Multi-disc memories, consisting of a file of discs mounted in a single housing, provide high-speed random access to a large memory store. The speed, flexibility and capacity of disc files bridge the gap between relatively low-capacity, high-speed magnetic storage drums and cores and the almost unlimited capacity of slow-speed magnetic tape systems.

Computer and data processing people think of a "bit" as a binary digit, or as the smallest unit of information. However, these abstract concepts do not describe the physical nature of a recorded bit.

To manufacturers and users of magnetic data storage devices, a bit has real substance—it is defined as a single magnetically polarized spot in a group of spots. In the case of Bryant disc files, these "spots" (or bits) are recorded within 768 concentric tracks on each disc face. These tracks are allocated to six recording zones on a 128-track-per-zone basis. Each zone is serviced by a read-write head which

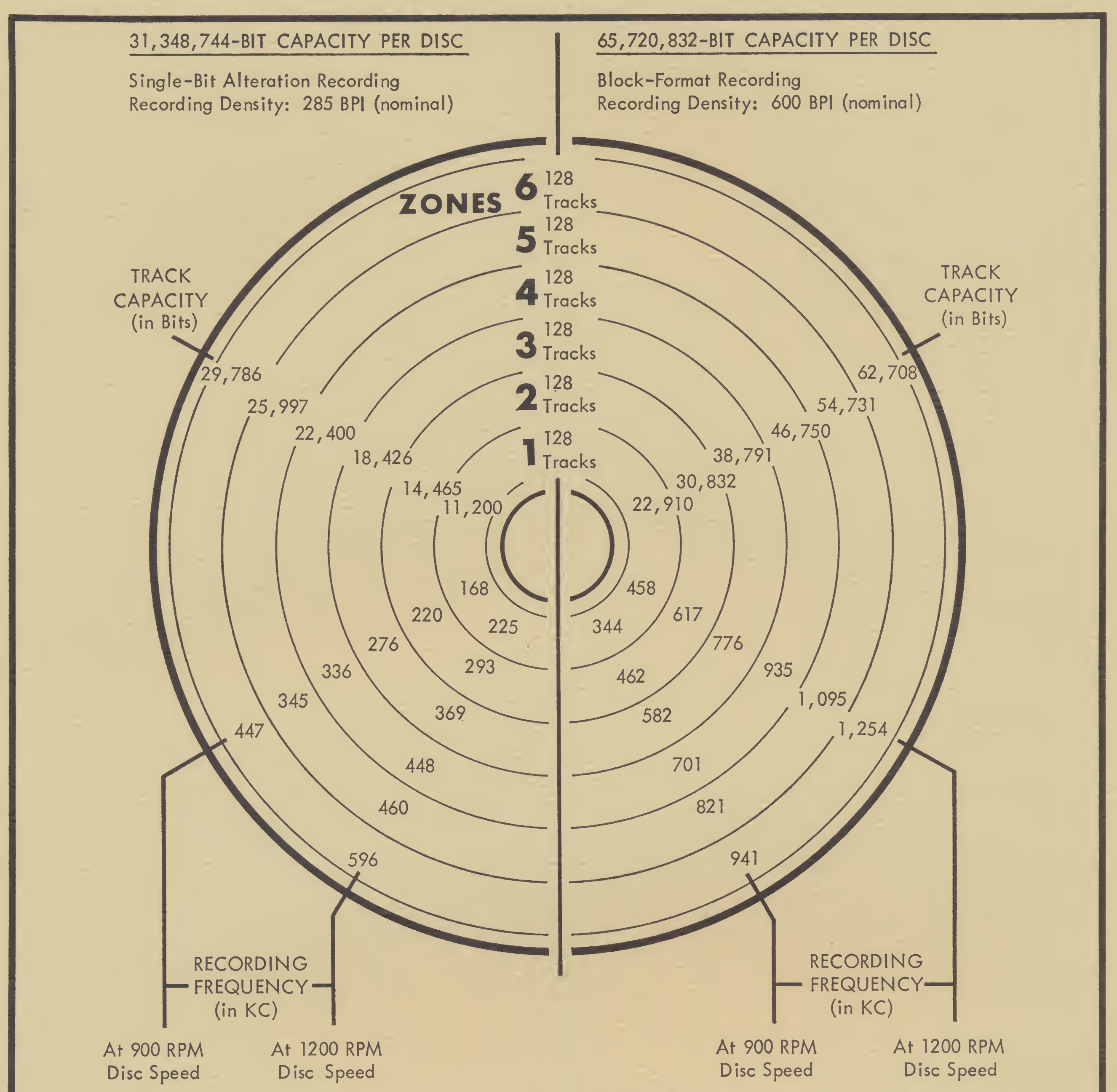


FIG. 2. RECORDING DISC has a maximum of 6 zones. A zone has an equal number of bits in each track. Track capacity depends on choice of recording format; recording frequency depends on choice of rotation speed.

is digitally positioned to any one of the 128 tracks. Fig. 1 shows a six-zone disc from which a pie-shaped slice is magnified, and a small area further magnified.

The bits on the disc surface can be visualized by applying a volatile solution containing micron-sized iron particles which are attracted to the magnetized area. When the base material evaporates, the iron particles adhere to the disc face, giving the distribution pattern shown in Fig. 1. By magnifying this pattern 12-1/2 times, the relationship of the tracks can be clearly discerned (upper left hand portion of Fig. 1). A further magnification of 80 times permits us to see a bit blown up 1,000 times.

The pattern shown was taken from a customer disc containing data used in actual day-to-day processing application. Zones 1, 2 and 3 were recorded at 224 kc; zones 4, 5 and 6 at 448 kc with bit interlacing. Rotational velocity of the disc file was 1,200 RPM.

The Series 4000 Disc Files shown in Fig. 1 comprise 39″-diameter magnesium discs rotating on a common shaft at 900 or 1200 RPM. The maximum-capacity equipment (Series 4000C) has 25 data discs (50 recording surfaces) plus a clock disc; capacity is 1,625,000,000 bits using 600 BPI (bits per inch), block-format recording, or 775,000,000 bits using 285 BPI, single-bit alteration recording. All Series 4000 Disc Files are available in one-disc modules ranging up in capacity from that of a single disc—that is, 65,000,000 bits using 600 BPI, block-format recording or 31,000,000 bits using 285 BPI, single-bit alteration.

Each of the three disc files—the Series 4000A, Series 4000B and Series 4000C—can be expanded in

TABLE 1—Typical Random-Access Times for a File with a Total of Twelve Discs[1]

Parameters	Single-Track	64-Track	128-Track	Average
	Type of Movement			
Positioning Time[2] (ms)	23	70	120	74
Track Verification Time (ms)	20	20	20	20
Average Latency Time (ms)	25	25	25	25
Access Time (ms)	68	115	165	119[3]

1. Includes discs used for any purpose, such as data storage, timing and track verification.
2. Maximum positioning time—for files with 1 to 8 data discs is 120 ms, with 9 to 14 data discs is 140 ms, and with 15 to 25 data discs is 165 ms. For less than 0.1% of the possible position combinations, positioning time can exceed these specifications—but by no more than 20%.
3. Based on tests of positioning time from each track to every other track.

TABLE 2—Track Capacity for 6-zone, 3-zone, 2-zone and 1-zone Recording

6 Zone	3 Zone	2 Zone	1 Zone	INNERMOST TRACK CAPACITY Single Bit	INNERMOST TRACK CAPACITY Block Format
Zone 1	1	1		11,200	22,910
2				14,465	30,832
3	2		1*	18,426	38,791
4		2		22,400	46,750
5	3			25,997	54,731
6				29,786	62,708

*Recording area begins on Zone "3" in Fig. 2 so as not to exceed the maximum permissible BPI.

the field after the file is purchased by adding discs (modules) until the maximum number of discs for the particular machine size is reached. The "A"-size machine has a capacity of seven total discs (six data discs and one clock disc); the "B"-size machine has a capacity of 14 total discs (13 data discs and one clock disc); the "C"-size machine has a capacity of 25 total discs, if an electronic page is used, and 26 total discs without the page (24 data discs and one clock disc in the former case and 25 data discs and one clock disc in the latter case). This flexibility permits the user to select the most economic machine size for his particular application.

Data Storage

Information is recorded in 768 concentric tracks on each data disc face by six magnetic read/write heads. A digital hydraulic positioner moves the heads to any one of the 128 tracks accessed by each head. One digital positioner is supplied for an entire file; all heads associated with all data disc faces are moved simultaneously. Each positioning operation accesses 1/128th of the full file capacity, which permits a large parallel recording capability. Data rates above seven megacycles have been achieved at nominal bit densities (270 BPI recording on each of 28 tracks in parallel).

Access Time

Random access time of a 1200-RPM file without repositioning the heads averages 25 milliseconds. This period includes only disc latency—the delay involved

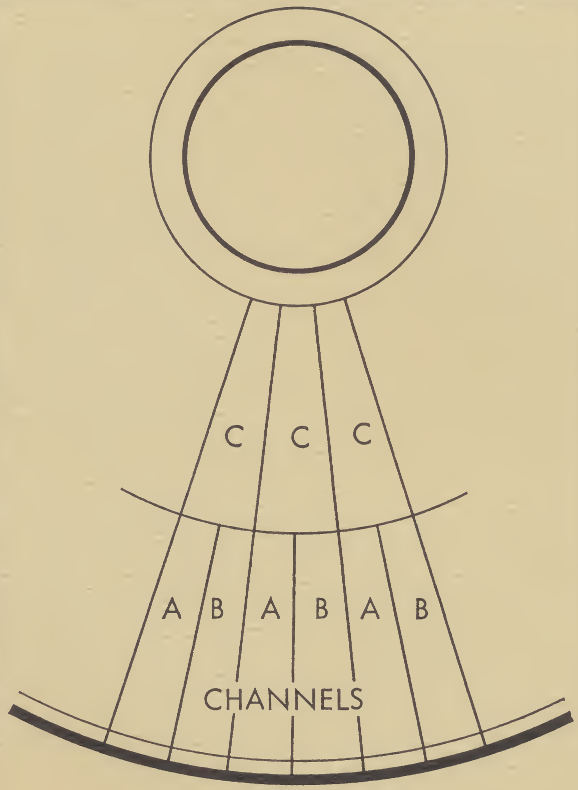


FIG. 3. OUTER TRACKS can be shared by channels A and B to provide channel capacity equal to that of channel C on inner track.

as a memory location rotates around to the magnetic head. Average head positioning time on a random basis is approximately 100 milliseconds; this time can be significantly decreased using short-stroke programs which require positioning over physically close tracks.

Confirmation that the positioning system has moved the heads to the addressed track, and that the heads have stabilized for read/write operation is provided in either of two ways at the user's option. Address data can be prerecorded in each track for comparison with applied addresses and, when a predetermined number of these compare successfully, a track-verification signal is generated to initiate read/write operations. Alternatively, the address data can be prerecorded in the 128 tracks under one of the heads on the spare (clock) disc face. This one head, then, provides the track verification control for the entire file. Both track-verification techniques permit the computer to proceed with other operations after it has transmitted a new address to the file, until the computer receives a track verification signal to indicate that the file is ready for read/write operations.

Operating Speeds

Disc file operating speeds are best measured in terms of transactions per unit of time. Operational rates on a serial basis have exceeded 25,000 transactions per hour on a full random-access basis. Significantly higher rates have been obtained by minimizing the number of positioning operations and the distances moved (see Table 1). Optimum use to reduce

BRYANT COMPUTER PRODUCTS
850 LADD ROAD • WALLED LAKE, MICHIGAN
A Division of Ex-Cell-O Corporation